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The spin flip in the theory of magnetic breakdown: magnetoresistance*

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The theory of magnetic breakdown in metals taking into account the existence of spin and spin–orbit interaction of conduction electrons is developed. The galvanomagnetic properties of a magnetic breakdown linked-orbit network with one- and two-dimensional topology are calculated for the case of a coherent motion of conduction electrons on the small orbits of network. The double-peak structure of magnetic breakdown oscillations for Zn is explained.

1. Introduction

The tunnelling of conduction electrons (CE) between neighbouring sheets of the Fermi surface in a high magnetic field, known as magnetic breakdown (MB), can have profound effects on the transport properties of metals at low temperatures [1]. The semiclassical CE orbits in a magnetic field H are defined by the intersection of the Fermi surface with planes perpendicular to the H direction. The significance of the MB effect follows from its ability to alter greatly the topology of CE orbits coupled by an MB junction. The plane MB network of coupled orbits appears in k-space. The CE motion acquires a probability nature. The CE wave functions of different arms of the network are coupled by s-matrices (2×2) of the MB scattering. Knowledge of s-matrices permits to calculate several macroscopic characteristics of the MB metals [1], in particular, magnetoresistance [1,2].

The metals with an MB network containing small orbits [2] are of particular interest. The condition of coherent motion of CE [1] $\{\tau, \tau_{sa}\} \gg 1/\omega_c$ is realized for small orbits at a significantly weaker restriction on both purity of the samples and temperature than the one for large semiclassical orbits. Here, ω_c is a typical cyclotron frequency, τ_{sa}^{-1} is the frequency of the small angle scattering [1], and τ is the relaxation transport time. These orbits are so small that they can be considered as "quantum switch" points which determine the CE motion on the entire MB network. This leads to specific oscillations of kinetic coefficients with a period corresponding to the area of the small orbit. However, the existing theory [1, 2] was not able to explain the experimental double-peak structure of the galvanomagnetic oscillations in zinc [2].

2. The method of calculation

In recent work [3] it was shown clearly that in the theory of MB it is necessary to take into account the CE spin and the spin–orbit interaction (SOI). In the presence of these factors both structure and form (4×4) of the s-matrix are changed significantly and the probability of MB with spin flip appears. Also the MB field H_0^α is renormalized. The semiclassical orbits become double due to spin splitting. The SOI influence on the theory of MB is described by a single microscopic parameter α. α is a ratio of off-diagonal (according to band number) matrix ele-

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